7/2/98

SUBJ: POWER CONDITIONING DEVICES AT FAA FACILITIES

1. **PURPOSE.** This order provides selection guidance for electrical power conditioning devices (PCD) and clarifies the conditions for which their use is authorized in the National Airspace System (NAS) facilities. It shall be used in conjunction with the latest editions of Order 6030.20, Electrical Power Policy, and Order 6950.2, Implementation of Electrical Power Policy at National Airspace System Facilities.

2. **DISTRIBUTION.** This order is distributed to the division level in the Airway Facilities, Office of Communication Navigation, and Surveillance Systems, Office of System Architecture and Investment Analysis and Office of Acquisitions in Washington; to division level in the FAA Logistics Center and the FAA Academy at the Aeronautical Center; to the division level in the Office of Communication Navigation and Surveillance Engineering and Test Division at the Technical Center; to the branch level in the regional Airway Facilities divisions; and to all Airway Facilities field offices with a standard distribution.

3. **CANCELLATION.** Order 6950.25, Use of Electrical Power Conditioning Devices at FAA Facilities, Dated 10/31/85 is canceled.

4. **BACKGROUND.** Orders 6030.20, and 6950.2 establish policy and implementation guidance for electrical power systems supporting NAS facilities. Changes in the design of modern electronic equipment have resulted in an increased susceptibility to power disturbances. When facility equipment operation is affected by the level of power quality available, Order 6950.2 allows the consideration of power conditioning devices to sustain the required reliability, maintainability, and availability (RMA) of this equipment. Power conditioning devices shall only be used where necessary, predicated upon site-specific conditions.

5. **EXPLANATION OF CHANGES.** Extensive revisions to this order have been performed to comply with Public Law 104-113, H.R. 2196, the National Technology Transfer and Advancement Act of 1996, and to clarify outdated PCD requirements contained in the existing order.

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Initiated By: ANS-600

6. APPLICATION.

a. This order shall be used when the electrical power systems and configurations listed in Orders 6030.20 and 6950.2 are insufficient to provide the quality of electrical power necessary for reliable equipment operation.

b. This order applies to all FAA facilities in the NAS.

7. QUALIFICATION CRITERIA.

a. Power synthesis devices; e.g., static Uninterrupted Power Supply (UPS), shall only provide service to equipment that is required to be operational for the safety of air traffic, and where it has been determined that its operation is adversely affected by power disturbances as discussed in paragraph 7b.

b. Power conditioning devices shall only be considered after it has been determined that the facility is up to current standards and the nature of the disturbance affecting the equipment identified. Documented efforts shall be made to ensure that the facility is within current standards. The facility power systems shall be considered insufficient to provide the quality of electrical power necessary for reliable equipment operation if any of the conditions below exist.

(1) Power disturbances that fall outside of the New CBEMA Curve, Supply Voltage Tolerance Envelope for Information Technology Equipment, see Graph 1, Appendix 2, Power Problem Analysis Guidelines, may disrupt equipment critical to the operation of the NAS.

(2) Power disturbances are frequent and are of a nature that may result in damage to equipment components.

(3) The number of facility outages (interruptions to services) due to power disturbances are considered unacceptable for reliable operation of the NAS.

(4) Power disturbances result in outages requiring manual intervention to restore service at unmanned facilities.

c. If it is determined that the quality of the electrical power system is insufficient and modification of the existing Federal Aviation Administration equipment to improve its performance is not feasible, a PCD may be used to upgrade the system to an acceptable level.

8. **DEVICE SELECTION AND GUIDANCE.**

a. Utilize Appendix 1, Definitions and Terms, to facilitate uniform communication and interpretation when describing power conditioning devices and power disturbances.

b. A power problem corrective matrix has been included as table 2 of appendix 2. This has been provided as a guide to select a PCD. Final selection of PCD solution shall be based on required maintenance intervals, life cycle costs, and impact to facility.

c. Facility wiring, grounding, electric service capacity, and the standby power system must be compatible with the PCD. An engineering evaluation of the electrical distribution system, including the studies required by the latest edition of Order 6950.27, Short Circuit Analysis and Protective Device Coordination Study, and voltage drop calculations per IEEE Std 241, Chapter 3, shall be performed prior to the installation of a PCD. Facility standards shall be used to the most practical extent. Analysis shall include load current profiles from starting inrushes to steady state for all technical loads.

d. Building space and environmental; e.g., air conditioning, requirements shall be identified and included in the evaluation process.

e. Systems, subsystems, and equipment under configuration management shall not be modified until an approved configuration control decision is issued following a NAS change proposal (NCP) request. Specific systems, subsystems, and equipment under configuration control are listed in NAS-MD-001, National Airspace System Configuration Management.

9. **RESPONSIBLITIES.**

a. Regions shall periodically review facility service performance in accordance with the latest edition of Order 6040.15, National Airspace Performance Reporting System (NAPRS).

b. The appropriate Washington headquarters program office shall provide procurement guidance and installation standards for the major PCDs.

10. **IMPLEMENTATION.** All commissioned facilities shall be provided with electrical power that satisfies facility operational requirements and Orders 6030.20 and 6950.2. The guidelines contained in appendix 2 to this order shall be used to determine when that power does not meet minimum equipment requirements and to select an appropriate PCD unit.

Robert Long, Program Director
NAS Transition and Integration

APPENDIX 1. DEFINITIONS AND TERMS

1. **GENERAL**. To ensure uniform interpretation, the following definitions and terms shall be used in the discussion of power-related problems.

2. **DEFINITIONS.** Refer to IEEE Standard 1100 and IEEE Standard 1159 for additional definitions related to power disturbances. Table 1 under this appendix provides the characteristics of power system disturbances.

> **NOTE:** In all instances of use, permission has been granted to reprint Definitions from pages 25-37, Table 8-1 from pages 160-161 and Figure 8-1 from page 162 of IEEE Std 1100-1992, IEEE Recommended Practice for Powering and Grounding Sensitive Electronic Equipment (IEEE Emerald Book), and Table 2 from page 162 of IEEE Std 1159-1995, IEEE Recommended Practice for Monitoring Electric Power Quality.

a. **Transient**. A sub-cycle disturbance in the ac waveform that is evidenced by a sharp brief discontinuity of the waveform. May be of either polarity and may be additive from the nominal waveform.

b. **Noise**. Electrical noise is unwanted electrical signals that produce undesirable effects in the circuits of the control systems in which they occur

c. **Common-Mode Noise**. The noise voltage that appears equally and in phase from each current-carrying conductor to ground.

d. **Normal-Mode Noise**. See Transverse-Mode Noise. (With reference to load device input ac power.) Noise signals measurable between or among active circuit conductors feeding the subject load, but not between the equipment grounding conductor or associated signal reference structure and the active circuit conductors.

e. **Notch**. A switching (or other) disturbance of the normal power voltage waveform, lasting less than a half-cycle, which is initially of opposite polarity than the waveform, and is thus subtractive from the normal waveform in terms of the peak value of the disturbance voltage. This includes complete loss of voltage for up to a half-cycle.

f. **Voltage Distortion**. Any deviation from the nominal sine waveform of the ac line voltage.

g. **Sag**. A rms reduction in the ac voltage, at the power frequency, for durations from a half-cycle to a few seconds.

APPENDIX 1. DEFINITIONS AND TERMS (CONTINUED)

h. **Swell**. A rms increase in the ac voltage, at the power frequency, for durations from a half-cycle to a few seconds.

i. **Undervoltage**. A rms decrease in the ac voltage, at the power frequency, for durations greater than a few seconds.

j. **Overvoltage**. A rms increase in the ac voltage, at the power frequency, for durations greater than a few seconds.

k. **Momentary Interruption**. A type of short duration variation. The complete loss of voltage (<0.1 pu) on one or more phase conductors for a time period between 0.5 cycles and 3 seconds.

l. **Long-Term Interruption (Temporary)**. A type of short duration variation. The complete loss of voltage (<0.1 pu) on one or more phase conductors for a time period between 3 seconds and 1 minute.

m. **Frequency Deviation (Variation)**. An increase or decrease in the power frequency. The duration of a frequency deviation can be from several cycles to several hours.

3. **CORRECTIVE DEVICES**. Typical Power-Enhancement Devices descriptions are listed below and are primarily taken from IEEE Standard 1100, Table 8-1.

a. **Transient Voltage Surge Suppressor**. Various types of surge suppressors are available to limit circuit voltages. Devices vary by clamping, voltage, and energy handling ability. Typical devices are "crowbar" types like air gaps, gas discharge tubes, and nonlinear resistive types like thyrite valves, avalanche diodes, and metal oxide varistors. Also available are active suppressors that are able to clamp or limit surges regardless of where on the power sinewave the surges occur. These devices do not significantly affect energy consumption.

b. **Electrical Magnetic Interference/Radio Frequency Interference (EMI/RFI) Filter**. Series inductors with parallel capacitors. Good for low-energy, high-frequency noise.

APPENDIX 1. DEFINITIONS AND TERMS (CONTINUED)

c. **Isolation Transformer**. Transformer with physically different winding for primary and secondary. Often has single or multiple electrostatic shields to further reduce common-mode noise. Attenuates common-mode disturbances on the power supply conductors. Provides a local ground reference point. With taps, allows compensation of steady-state voltage drop-in feeders. Delta connected windings trap 3rd harmonic and its multiples (triplens).

d. **Voltage Regulator**. A variety of voltage regulation techniques are utilized. Common techniques include ferroresonant transformers, electronic tap switching transformers, and saturable reactor regulators

e. **Motor Generator**. Most often two separate devices, a motor and an alternator (generator), interconnected by a shaft or other mechanical means. Provide voltage regulation, noise/surge elimination, and waveform correction for voltage distortion.

f. **Standby Power System**. An inverter to which the load is switched after utility failure. There is some break in power when the transfer to and from utility power occurs. Usually comprised of a solid-state inverter, battery, and small battery charger. Inverter and battery backup operate as UPS, when normal power fails. In standby mode, the load is fed directly from the utility.

g. **Uninterruptible Power Supply**. Line interactive or rectifier/inverter technologies are most common. A battery supplies the power to the inverter during loss of input power. Maintain supply of regulated voltage, waveshaping, noise/surge violation for a period of time after power failure.

h. **Standby Engine Generator**. A generator set driven by a prime mover; e.g., diesel or spark-ignited engine. Means is provided for automatically starting the prime mover on failure of the normal service and for automatic transfer and operation of all required electrical circuits within 10 seconds.

APPENDIX 1. DEFINITIONS AND TERMS (CONTINUED)

TABLE 1. CATEGORIES AND TYPICAL CHARACTERISTICS OF POWER SYSTEM ELECTROMAGNETIC PHENOMENA

Categories	Typical Spectral Content	Typical Duration	Typical Voltage Magnitude
1.0 Transients			
1.1 Impulsive			
1.1.1 Nanosecond	5 ns rise	<50 ns	
1.1.2 Microsecond	1 μs rise	50 ns-1ms	
1.1.3 Millisecond	0.1 ms rise	> 1 ms	
1.2 Oscillatory			
1.2.1 Low Frequency	< 5 kHz	0.3-50 ms	0-4 pu
1.2.2 Medium Frequency	5-500 kHz	20 μs	0-8 pu
1.2.3 High Frequency	0.5-5 MHz	5 μs	0-4 pu
2.0 Short duration variations			
2.1 Instantaneous			
2.1.1 Sag		0.5-30 cycles	0.1-0.9 pu
2.1.2 Swell		0.5-30 cycles	1.1-1.8 pu
2.2 Momentary			
2.2.1 Interruption		0.5 cycles-3 s	< 0.1 pu
2.2.2 Sag		30 cycles-3 s	0.1-0.9 pu
2.2.3 Swell		30 cycles-3 s	1.1-1.4 pu
2.3 Temporary			
2.3.1 Interruption		3 s - 1 min	<0.1 pu
2.3.2 Sag		3 s - 1 min	0.1-0.9 pu
2.3.3 Swell		3 s - 1 min	1.1-1.2 pu
3.0 Long duration variations			
3.1 Interruption, sustained		> 1 min	0.0 pu
3.2 Undervoltages		> 1 min	0.8-0.9 pu
3.3 Overvoltages		> 1 min	1.1-1.2 pu
4.0 Voltage imbalance		steady state	0.5-2%
5.0 Waveform distortion			
5.1 DC offset		steady state	0-0.1%
5.2 Harmonics	0-100th H	steady state	0-20%
5.3 Interharmonics	0-6 kHz	steady state	0-2 %
5.4 Notching		steady state	
5.5 Noise	broad band	steady state	0-1%
6.0 Voltage fluctuations	< 25 Hz	intermittent	0.1-7%
7.0 Power frequency variations		< 10 s	

This is a historical table for categorizing electromagnetic phenomena. This table is not a tolerance standard, design guide or requirement.

APPENDIX 2. POWER PROBLEM ANALYSIS GUIDELINES

1. **GENERAL.** This appendix contains the Power Problem Corrective Matrix, Table 2 and the evaluation procedure to be performed in the selection of a cost-effective PCD.

2. **FACILITY SURVEY PROCEDURE.** Accomplish the following:

a. Review the design, performance, and installation of the electrical distribution and grounding systems to establish that they are in accordance with current standards and requirements.

b. A power quality evaluation of the utility electrical power, measured at the facility service entrance, with and without the facility load. Utilize a power disturbance analyzer to identify the power anomalies affecting equipment operation. The anomalies shall be evaluated to determine their origin. Conduct a complete facility grounding system inspection using the latest version of Order 6950.19, Practices and Procedures for Lightning Protection Grounding, Bonding, and Shielding Implementation, Appendix 3, Inspection Checklist.

c. Coordinate corrective measures with the utility to bring the service entrance power profile within the limits established under Range A, Figure B1, Annex B of ANSI Standard C84.1 (See Graph 2).

d. If utility corrective measures are not effective in improving equipment operation, then investigate internal sources of disruption using the following procedure.

(1) Identify and document the facility loads and their power characteristics including kW, kVA, PF, current harmonic distortion.

(2) Evaluate equipment operation for design defects and/or malfunctions.

(3) Evaluate operational procedures impacting equipment operation.

e. Accomplish any remedial actions resulting from the above investigations.

f. If operational results are still not acceptable, use the Power Problem Corrective Matrix in appendix 2, table 2 to select an appropriate PCD. PCD solutions are not limited to the matrix but provide typical solutions. Application of the PCD will be based upon the actual performance of the proposed PCS equipment and not the table listing.

APPENDIX 2. POWER PROBLEM ANALYSIS GUIDELINES (CONTINUED)

3. **USE OF POWER PROBLEM CORRECTIVE MATRIX.** The matrix is presented in appendix 2, table 2. In some situations, more than one solution or combination of devices may be indicated by the matrix. Based on operational requirements, determine all possible solutions. One or more PCDs may be required for various facility loads. Final selection shall consider required maintenance intervals, cost-effectiveness, and impact to facility operation.

APPENDIX 2. POWER PROBLEM ANALYSIS GUIDELINES (CONTINUED)

TABLE 1. RECOMMENDED THRESHOLD SETTINGS FOR POWER MONITORS AT THE EQUIPMENT TERMINALS (UTILIZATION VOLTAGE)

Nominal RMS Voltage (V_N)	Swell (V_H)	Sag (V_L)	Transient Impulse (V_I)	Frequency Sensitivity (Hz)	Voltage Sensitivity (V_S)
120	127[1]	104[1]	[2]130% of V_N	±0.3[3]	1.5
208	220[1]	181[1]	"	"	"
240	254[1]	209[1]	"	"	"
277	293	240	"	"	"
480	508	410	"	"	"
Neutral to Ground Voltage					
120	N.A.	N.A.	[3]10-20% of V_N	N.A.	[3]3.0

Notes:

1. The above recommended threshold settings are to be used in the absence of specific equipment sensitivity values.

2. To assist in evaluation of data gathered, use the New CBEMA Curve, Supply Voltage Tolerance Envelope for Information Technology Equipment. (See Graph 1)

3. The following companies produce power monitoring and recording instruments useful in performing the power quality evaluation.

(a) Basic Measuring Instruments (BMI)

(b) Dranetz Technologies

(c) Reliable Power Meters

(d) Other equal manufacturers

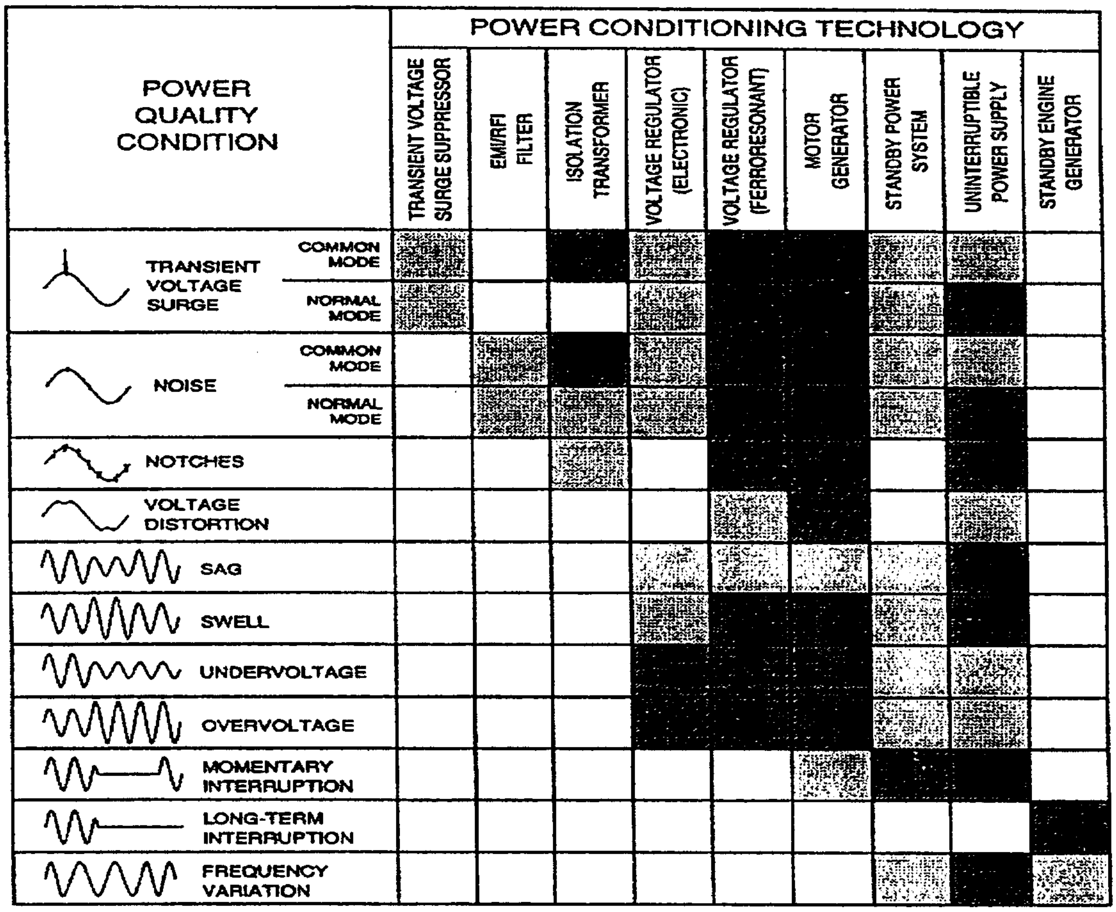
[1] FAA-G-2100F
[2] FAA-STD-020b
[3] IEEE Std 1100-1992, Copyright © 1995. IEEE. All rights reserved.

APPENDIX 2. POWER PROBLEM ANALYSIS GUIDELINES (CONTINUED)

TABLE 2. POWER PROBLEM CORRECTIVE MATRIX

IEEE
Std 1100-1992

Summary of Performance Features for Various Types of Power Conditioning Equipment



IT IS REASONABLE TO EXPECT THAT THE INDICATED CONDITION WILL BE CORRECTED BY THE INDICATED POWER CONDITIONING TECHNOLOGY.

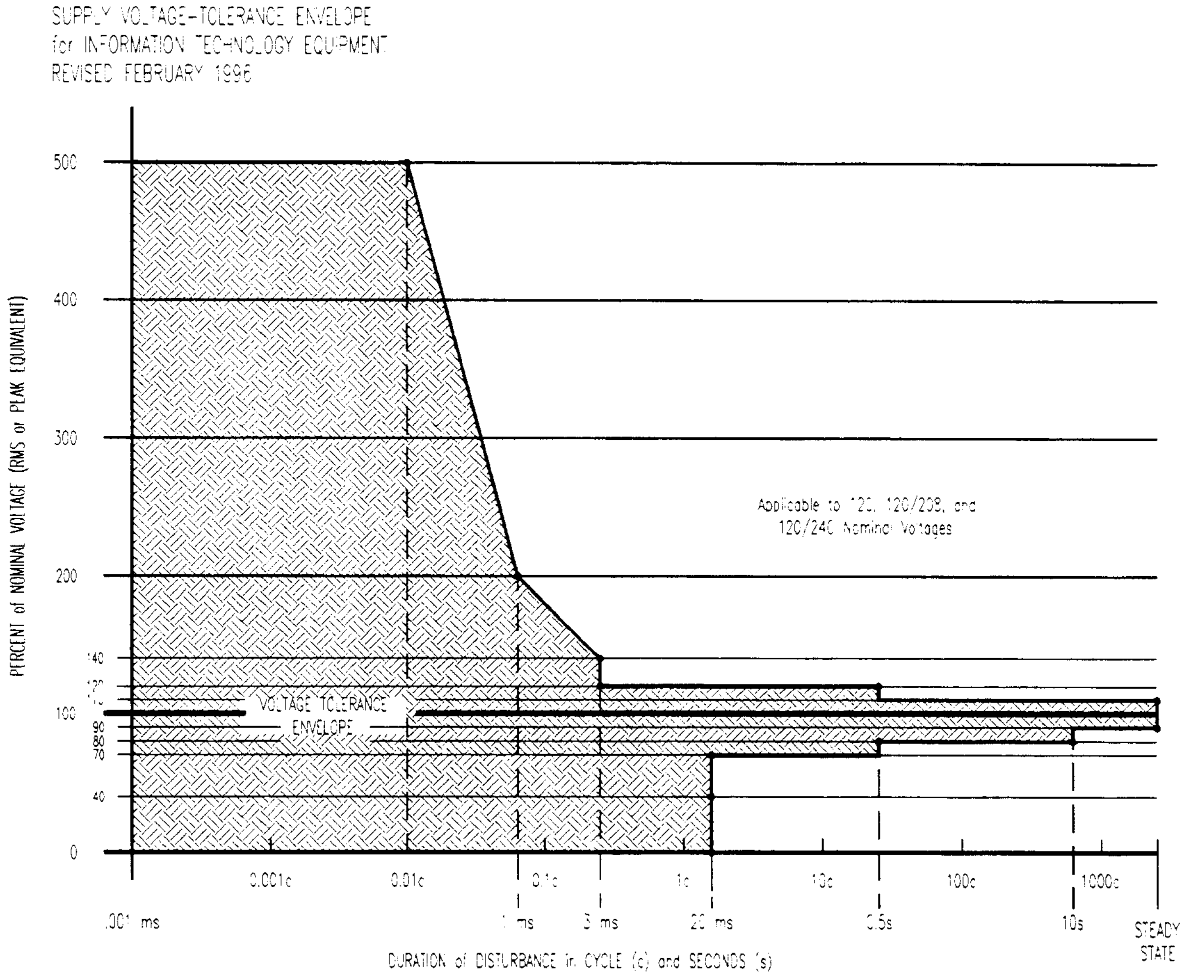
THERE IS A SIGNIFICANT VARIATION IN POWER CONDITIONING PRODUCT PERFORMANCE. THE INDICATED CONDITION MAY OR MAY NOT BE FULLY CORRECTABLE BY THE INDICATED TECHNOLOGY.

<u>NOTE:</u> Life Cycle Cost equals ((EC+IC+SP+TC+HD)/SL)+OC+MC in Dollars per year

Equipment Cost (EC)
Installation Cost (IC)
Spare Parts (SP)
Training Costs (TC)
Service Life Years (SL)
Operating Costs/Year (OC)
Maintenance Cost/Year (MC)
Hazardous Material Disposal Costs (HD)

APPENDIX 2. POWER PROBLEM ANALYSIS GUIDELINES (CONTINUED)

GRAPH 1. NEW CBEMA CURVE



ITC granted the FAA permission to reproduce the CBEMA/ITI Curve, revised 2/96.

APPENDIX 2. POWER PROBLEM ANALYSIS GUIDELINES (CONTINUED)

GRAPH 2. C84.1, UTILITY POWER PROFILE

ANSI C84.1-1995

Annex B
(informative)
Illustration of voltage ranges of table 1

Figure B1 shows the basis of the Range A and Range B limits of table 1. The limits in table 1 were determined by multiplying the limits shown in this chart by the ratio of each nominal system voltage to the 120-volt base. [For exceptions, see note (d) to figure B1.]

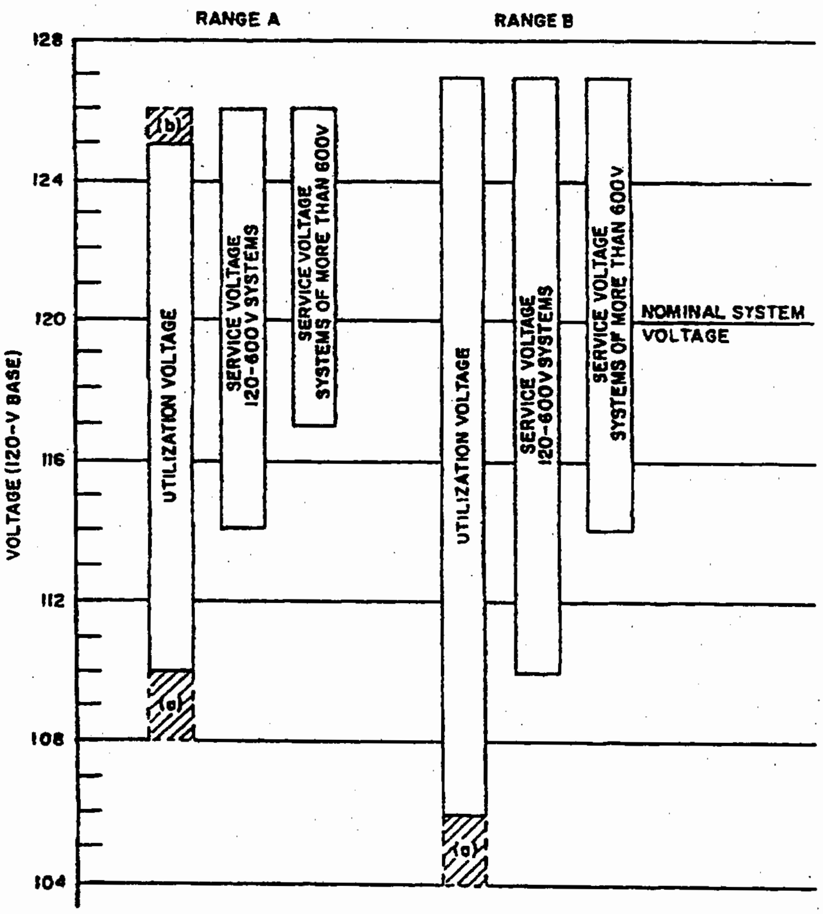


Figure B1

NOTES
(a) These shaded portions of the ranges do not apply to circuits supplying lighting loads. See note 1 to table 1.
(b) This shaded portion of the range does not apply to 120-600-volt systems. See note (c) to table 1.
(c) The difference between minimum service and minimum utilization voltages is intended to allow for voltage drop in the customer's wiring system. This difference is greater for service at more than 600 volts to allow for additional voltage drop in transformations between service voltage and utilization equipment.
(d) The Range B utilization voltage limits in table 1 for 6900-volt and 13800-volt systems are 90% and 110% of the voltage ratings of the standard motors used in these systems and deviate slightly from this figure.